The International Journal Of Engineering And Science (IJES)
|| Volume || 5 || Issue || 6 || Pages || PP -40-45 || 2016 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Experimental Study on Corrosion of Wire Rope Strands under Sulfuric Acid Attack

M.Meknassi[1], A. Tijani[1, 2], N.Mouhib[1], M. El Ghorba[1]

[1]*Laboratory Of Control And Mechanical Characterization Of Materials And Structures, National Higher School Of Electricity And Mechanics, Bp 8118 Oasis, Hassan Ii University, Casablanca, Morocco*

[2] *Laboratory Of Physics Of The Atmosphere And Modeling, Fst Mohammedia, Bp 146 - Mohammedia*

ABSTRACT

A corrosive medium is typically found in the working environment of a wire rope. The wire rope structure has certain characteristics such as complex details, high working stress, and extremely difficult control. Thus, corrosion is the key problem related to the use of wire ropes.

The corrosion behaviors of strands extracted from wire rope of type 19x7 in acid medium was investigated in this paper. The results obtained from tensile tests on virgin and corroded specimens show a decrease in strength as function of immersion hours. This progressive decrease of strength allowed us to quantify the damage. Thereafter, and with the establishment of the Damage-Reliability relationship, three stages of damage are distinguished and the value of the critical life fraction is identified ($\beta_C = 0.62$).

Keywords: *Wire rope, strand, corrosion, damage, reliability.*

Date of Submission: 25 March 2016 — Date of Accepted: 17 June 2016

I. INTRODUCTION

Wire ropes combine two very useful properties: high axial strength and flexibility in bending. These properties convert wire ropes into indispensable load transmission elements for many industrial applications [1]. Wire ropes are frequently used for load transmission.

The wire ropes are widely used in harbours, on ships and in many industrial fields. The safety of a wire rope is closely related to the life safety and equipment safety [2]. The quality and wearing degree of ropes significantly influences safety and reliability of mining hoists, cranes, elevators and air transportation.

Wire rope consists of three parts: wires, strands, and core. In the manufacture of rope, a predetermined number of wires are laid together to form a strand. Then a specific number of strands are laid together around a core to form the wire rope (Fig.1). A wire rope is able to carry loads in the longitudinal direction while being flexible in the lateral direction. Steel wires that have been drawn from steel with high percentage of carbon and a fine pearlitic microstructure are preferred for wire ropes [3]. Lubricants are added inside the wire rope structure.

Fig.1 Basic components of a typical wire rope

The humid and oxygen-rich working environment of the wire ropes can cause corrosion. Corrosion reduces the cross section area of steel wire ropes as well as their flexibility and mechanical properties. Data shows that corrosion may cause the wire rope to lose more than 30% of its strength and even 50% in some cases. Besides, steel wire ropes become loose after intensive corrosion. This can be explained by the accelerating wear between steel strands by abrasion after rust has entered the wire rope core. As well, the condition of the oil will also be damaged when aggressive water enters the core, which weakens the lubrication and increases wear between the internal strand wires [4].

The proposed study consists to make an experimental procedure of corrosion degradation of strands extracted from wire rope of type 19x7 under sulfuric acid attack, in order to predict the damage by corrosion of strands, based up on experimental tensile tests, and subsequently determine the critical life fraction βc.

II. MATERIALS

The tested specimens are strands extracted from wire rope of type 19x7 and anti gyratory structure (1x7 + 6x7 + 12x7) 8 mm in diameter, composed of steel light greased, metal core, right cross, preformed, used especially in tower cranes and suspension bridges (Fig.2).
They are composed of two layers of strands wired in opposite directions, which avoids the rotation of the suspended load when the lift height is important and that the burden is not guided. Their use requires a certain amount of caution at rest and during operation. This construction, robust nature, is widely used for common applications and especially for lifting heights reduced.

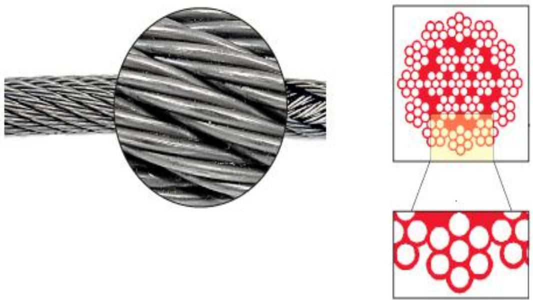

Fig. 2 Cross section of a 19*7 "antigiratoire" wire rope

The characteristics of this cable are shown in Table 1, the Ultimate Load is 41,14KN (Table 1).

Table 1 Mechanical properties of the material

Cable diameter (mm)	8mm
Design	19*7 (1 * 7 + 6 * 7 + 12 *7)
Construction du toron	6/1
Young modulus of the wire (MPa)	200 Gpa
Surface quality of the wires	Galvanized steel
Twisting direction	Right
Type de l'âme	RHR
Mass per unit length (kg/m)	0,272 kg/m
Lubrification	A2/W-3
Minimum breaking strength	41,14KN
Poisson's ratio	ν = 0,3

The studied strands are composed of 7 individual wires; a core wire and six peripheral wires disposed helically around the core wire.
The minimum length of the specimens is equal to the length of the test 200 mm plus the necessary for the mooring. Therefore, a length of 300 mm is anticipated as the length of the test for the strands. The measurements tolerance in the length is ± a millimeter for all samples [5]. Dimensions of the strand are shown in Fig.3.

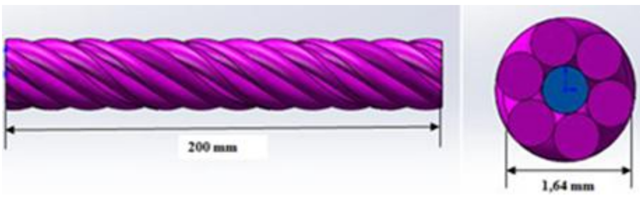

Fig. 3 Dimensions of the studied strand

The chemical composition is obtained by spectrometric analysis using an advanced spark spectrometers for precise analysis of metals (Fig.4).

Fig. 4 Advanced spark spectrometers

The apparatus used for mechanical characterization tests is a traction machine "Zwick Roell" of a 10 KN load cell (Fig.5).

Fig.5 Zwick Roell testing machine (10 KN)

III. METHODS

The strands were cut at a length of 300 mm. The areas of 100 mm length were defined in the middle of the specimen (Fig.6), and then they were immersed in 30% H_2SO_4 solution at room temperature (Fig.7) [6].

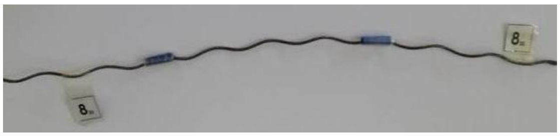

Fig.6 strand prepared for immersion

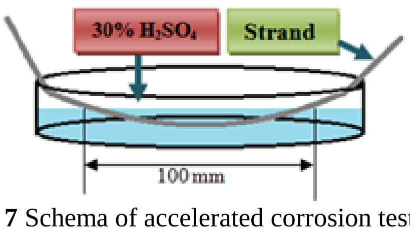

Fig. 7 Schema of accelerated corrosion testing

IV. RESULTS AND DISCUSSION

IV.1 Chemical characterization

The chemical composition of the steel wire is given in Tables 2.

Table 2: The Chemical composition of the material

Composition	C	Si	Mn	S	P
Percentage	1,478	2,04	3	0,144	0,091

IV.2 Static tensile test on virgin and corroded strands

The curves of the applied force in function of the elongation of the virgin and corroded strands are given in Fig.8.

The mechanical tensile tests show only a little decline in the breaking force after 8 hours of immersion; this decline increases with the time of immersion.

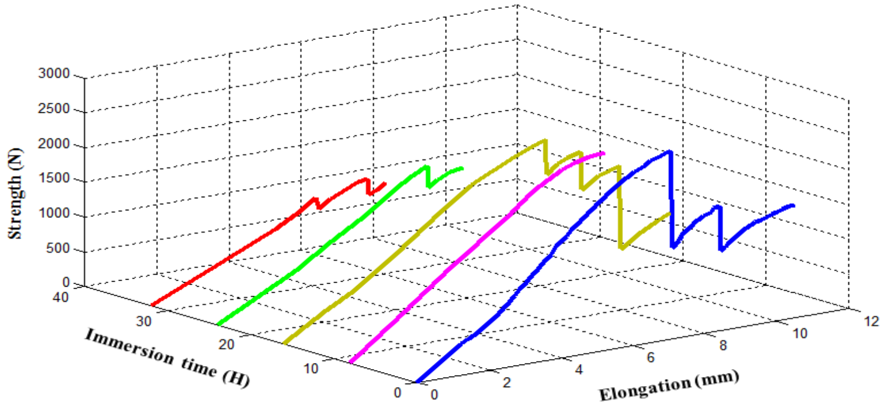

Fig.8 Comparison of tensile curves of corroded strands

The values of residual ultimate strength reported in Table 3

Immersion time (H)	0	8	16	24	32
Residual ultimate force (N)	2558	2400	2122	1666	1272

IV.3 Calculation of static damage

The model of static damage (D) aims to determine the loss of force whose variations are mainly due to damage. Then we quantify the damage by the variable D expressed as [7]:

$$D = \frac{1 - \frac{Fur}{Fu}}{1 - \frac{Fa}{Fu}} \qquad (2)$$

Where F_u is the value of the maximum ultimate strength, F_{ur} is the value of the ultimate strength and F_a is the force just before the break.

During the course of the test, we are following the phenomenon of damage from the virgin to the degraded state of the specimen by measuring the ultimate residual force in function of the life fraction β.

In our case, β is given by the following equation:

$$\beta = \frac{t_i}{t_f} \qquad (3)$$

Where β is the life fraction, t_i is the initial time of corrosion; t_f is the time of strands in the final state.

The variation of the static damage according to the life fraction is illustrated by the curve with the following conditions (Fig.9):

$\beta = 0 \rightarrow \; Fur = Fu \; \rightarrow D = 0$
$\beta = 1 \rightarrow Fur = Fa \; \rightarrow D = 1$

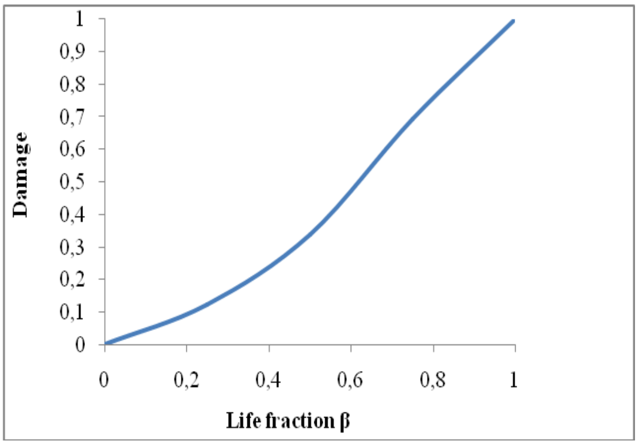

Fig.9 Static damage due to corrosion of strands according to the life fraction

The increase of the damage means the loss in resistance of static tensile strength; this loss evolves as the time becomes more important.

IV.4 Relationship Damage –Reliability

When a system is in operation under static solicitations, its physical properties undergo a progressive degradation, so we often need to reduce the probability of sudden failure.

The reliability theory permits to evaluate the probability of failure and considers the uncertainties associated with different variables.

Reliability varies inversely to the damage [8]. Intuitively, there must be a relationship between these two parameters. This allows us to write:

$$R(\beta) + D(\beta) = 1 \quad (4)$$

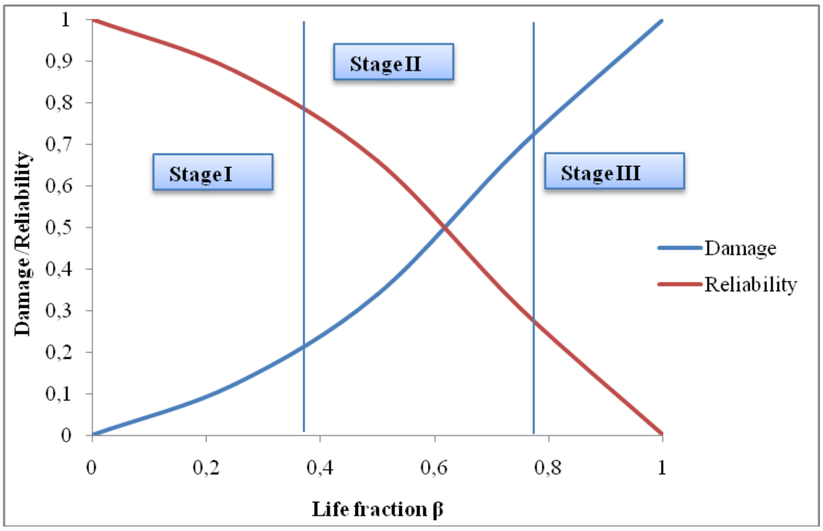

Fig.10 Superposition of static curves Damage –Reliability

The Increasing damage is necessarily accompanied by the decrease of the reliability (Fig. 10). At the beginning, we have the damage initiation area (stage I), then specimens start to lose their internal resistance, it is the progressive damage zone (stage II) which requires maintenance. Starting from 80% of the damage (20% reliability) the specimens under tension are in the brutal damage zone.

The advantage of determining the relationship between the damage and the reliability is that it allows, in particular, to know the values of life fractions when the damage becomes progressive and critical which corresponds in this case to βc = 0.62.

V. CONCLUSION

In this study, an experimental protocol was developed to study the effects of corrosion on the mechanical properties of strands extracted from steel wire rope of type 19x7 with anti gyratory structure. Tensile tests are performed on virgin and on corroded strands after 8h, 16h, 24h and 32h of immersion. The acid medium change the strands mechanical characterization and the tensile mechanical test showed a decrease in tensile strength after only 8 hours of immersion. The establishment of the relationship Damage-Reliability allowed identifying the three stages of damage due to corrosion: Stage I that corresponds to the initiation of an elastic damage, Stage II that corresponds to progressive damage and Stage III that represents the brutal damage. At the same time, the value of critical life fraction is determined ($\beta_C = 0.62$) which permits us to predict the instant of critical damage and thus to intervene at the appropriate moment.

REFERENCES

[1]. Argatov II, Gomez X, Tato W, Urchegui MA,Wear evolution in a stranded rope under cyclic bending: Implications to fatigue life estimation,*Wear*, 2011;271:2857–67.

[2]. K. Feyrer, Wire Ropes—Tension ,Endurance, Reliability: *Springer-Verlag,Ger- many*,2007.H.H.

[3]. Jianxin CJC, Wei GWG. Study and development on detecting device of wire rope localized fault. In: Proceedings of the 4th World Congress on Intelligent Control and Automation Cat *No02EX527, 2002. p.* 1

[4]. W. Songquan, Z .Dekun, W. Dagang, Z. Zefeng, Electrochemical corrosion behavior of steel wires in a coalmine with a corrosive, *Mining Science and Technology (China*), 21 (2011) 71e76.

[5]. A. Meksem, *Probabilistic approach and experimental characterization of the behavior of wire rope hoist*, Ph.D. Thesis, ENSEM, University Hassan 2, Ain Chock, Casablanca, 2010.

[6]. M.Meknassi, N.Mouhib, A.Tijani, M. El Ghorba, Experimental study of wires extracted from steel wire rope and exposed to sulfuric acid, *IPASJ International Journal of Mechanical Engineering (IIJME)*, Volume 3, Issue 4, April 2015, ISSN 2321-6441.

[7]. N.Mouhib, H.Ouaomar, M.Lahlou, A.Ennaji, M. El Ghorba, Tensile test of a strand with 2 broken wires artificially damaged and life prediction,*The International Journal Of Engineering And Science (IJES)*, Vol.4, Issue .4 ,Pages ,PP.11-16, 2015 .ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805.

[8]. A. Chouairi, M. El Ghorba, A. Benali, A. Hachim K. El Had and M. Boudlal, Maintenance scheduling and reliability estimation of structural lifting cables using the theory of accelerated tests Approach based on reliability block diagrams, *International Journal of Innovation in Science and Mathematics (IJISM)*, Vol.2, Issue.1, January 2014, ISSN: 2347-9051, Pages: 4-10, United Kingdom.